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ABSTRACT

Seventy-one college general biology students were taught a unit in Mendelian genetics by the traditional lecture method. Emphasis was placed on meiotic formation of gametes, dominance, segregation, and independent assortment. The Punnett square model was used for all practice problems. While using this model, students were asked to: (1) identify ratios from the Punnett squares (requiring use of proportional reasoning); (2) identify combinations of gametes from parental genotypes (requiring use of combinatorial reasoning); and (3) estimate gamete or offspring probabilities (requiring use of probabilistic reasoning). Each of the 71 students was also given three Piagetian interview tasks to evaluate intellectual development in the areas of reasoning under question. The balance beam task, the electronic switch-box task, and colored squares and diamonds were used to test for proportional reasoning, combinatorial reasoning, and probabilistic reasoning respectively. Although Pearson correlations and factor analysis failed to show direct relationships among Piagetian tasks for the three kinds of reasoning and their corresponding occurrence in genetics problems, analysis of variance showed significant differences for all three reasoning types among concete-operation, transitional, and formal-operation students in a unit and post-test. Implications of these and other results are noted. (Author/JN)

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Relationships Between Formal-Operational Thought and Conceptual Difficulties in Genetics Problem Solving

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RELATIONSHIPS BETWEEN FORMAL-OPERATIONAL THOUGHT AND CONCEPTUAL DIFFICULTIES IN GENETICS PROBLEM-SOLVING

Abstract

Seventy-one college general biology students were taught a unit in Mendelian genetics by the traditional lecture method. Emphasis was placed on meiotic formation of gametes, the Law of Dominance, the Law of Segregation, and the Law of Independent Assortment. The Punnett square model was used for all practice problems. To build Punnett squares, students were required to identify the gamete types that could be produced by parent organisms; they were then asked to identify phenotype and genotype ratios from the resulting zygotic combinations. Estimations of the probability for gamete formations or zygote combinations were also required in practice problems. A unit test was followed, eight weeks later, with a content validated post-test to evaluate the students' retention of problem-solving skills. Both tests required students to use proportional reasoning (identifying ratios from the Punnett squares), combinatorial reasoning (identifying combinations of gametes from parental genotypes), and probabilistic reasoning (estimating gamete or offspring probabilities). Each of the seventy-one students was also given three Piagetian interview tasks to evaluate his intellectual development in the areas of reasoning under question. The balance beam task, the electronic switch-box task, and colored squares and diamonds were used to test for proportional reasoning, combinatorial reasoning, and probabilistic reasoning respectively. Pearson correlations and factor analysis failed to show direct relationships among Piagetian tasks for the three kinds of reasoning and their corresponding occurrence in genetics problems. Some correlations were higher between different reasoning

types than between similar types. Combinatorial with proportional reasoning on the post-test and interview tasks had a correlation of .44, while proportional with proportional from the same tests correlated at .32. Analysis of variance showed significant differences for all three reasoning types among concrete-operational, transitional and formal-operational students in both the unit test and post-test. Post hoc analysis of ANOVAs indicated that formal-operational students had significantly more success in the three reasoning areas than transitional students, and transitional students had significantly more success than concrete-operational students.

RELATIONSHIPS BETWEEN FORMAL-OPERATIONAL THOUGHT AND CONCEPTUAL DIFFICULTIES IN GENETICS PROBLEM-SOLVING

Purpose

The purpose of this study was to identify the relationships between certain aspects of formal-operational thought and conceptual difficulties related to problem-solving in Mendelian genetics. Proportional reasoning, combinatorial reasoning, and probabilistic reasoning are the areas of formal thought that were analyzed for relationships to difficulties in working with ratios from Punnett squares, gamete formation combinations, and chances of zygote formations.

In this study two overall questions were dealt with:

1. Are there direct relationships between student success on Piagetian tasks in proportional, combinatorial and probabilistic reasoning and success with corresponding types of reasoning seen in Mendelian genetics problems?

2. Will students who score well on Piagetian tasks show stronger retention of genetics problem-solving abilities on a post-test?

Theoretical Base

Teachers who accept as axiomatic the idea that the central purpose of education is to develop rational thought will seriously examine both their methodology and their subject matter in the light of this purpose.

Those devoted to teaching thinking rather than the mere recitation of facts have welcomed genetics to the biology curriculum as an area that involves students in problem-solving activities. However, most biology teachers who have tried to teach introductory Mendelian genetics have wrestled with the problem of why a large portion of their students do not master the ability to solve the problems.

The answer may lie at least in part in the intellectual capacities of the students.

Piagetian studies in science education have pointed out the value of relating curriculum to the stage development of students, but little emphasis has been aimed at the college biology classroom. A large percentage of college freshmen are not able to operate at a formal intellectual level (McKinnon & Renner, 1971; Haley & Good, 1976). A higher percentage of concrete-operational freshmen is found among those who are non-science majors (Maloney, 1981). Since general biology classes in colleges are populated mostly by those who will not be taking more specialized science courses, teachers can expect a large portion of their students to be below the formal-operational level.

Several researchers indicate that the Mendelian genetics concepts presented in introductory biology classes require formal intellectual operations of the students. Walker, Mertens, and Hendrix (1979) proposed that combinatorial reasoning, propositional logic, and the use of probabilistic reasoning are all necessary to the understanding of many of the basic principles of genetics.

If genetics problems truly do require formal intellectual abilities, there exists a serious discrepency between what many students are being asked to do and what they are able to do. More precise information needs to be gathered to clearly indicate the kinds of mental operations required of students in their attempts to solve genetics problems. Such information would be valuable in developing teaching methods appropriate to the intellectual levels of the students.

Procedure

The plan for a more specific identification of relationships between formal thought and conceptual difficulties in solving genetics problems involved the following steps:

1. For three weeks 71 college general biology students were lectured on Mendelian genetics by the same instructor. The lecture material was

traditional in content, consisting of an historial overview, meiosis and gamete formation, probability of gamete and zygote combinations, and phenotype and genotype ratios of classical crosses up through the dihybrid cross. Special emphasis was given to the Laws of Dominance, Segregation, and Independent Assortment.

2. A unit test involving objective questions and problems was given to the students at the completion of the lecture. Problems required students to identify ratios from Punnett squares, select all possible gamete combinations from a genotype, and calculate the probability of zygote combinations.
3. After eight weeks, with no additional genetics instruction, a content validated problem-solving test was given. This post-test covered the following genetics principles:
    (a) zygote formation ratios seen in Punnett squares,
    (b) the Law of Independent Assortment and gamete formation combinations, and
    (c) the probability of gamete and zygote formations.

    To eliminate the problem of forgotten terminology, a sheet of vocabulary definitions was made available with the problems.
4. The 71 students were given Piagetian task interviews over proportional reasoning, combinatorial reasoning, and probabilistic reasoning. These interviews were conducted within two weeks of the administration of the post-test. The balance beam task for proportional reasoning was used in the interviews. Protocols for this task were established by Inhelder and Piaget (1958). The electronic switch-box task (DeLuca, 1979) was used to measure combinatorial reasoning. Probabilistic reasoning was measured by the use of colored squares and diamonds with protocols

adapted in part from the Lawson Test and suggested by Shayer and Adey (1981).

5. The results from the interview tasks, the unit test, and the post-test were analyzed by three statistical methods. Pearson correlations were sought for the intellectual levels with reasoning types for each test. Results of the tasks and post-test items were subjected to factor analysis, and analysis of variance was used as a test of significance for the means from each test.

Results

Specific identification of areas of formal thought related to corresponding areas in genetics were not conclusively shown by any of the statistical measures used. Interview tasks and post-test items should provide the most direct measure of the correspondence of reasoning types. However, correlations for the interview tasks with the post-test items in proportional reasoning were .08, .06, and .19 for the concrete, transitional, and formal students, respectively. Correlations were often higher between different reasoning types than between similar types. For instance, combinatorial/proportional on the interview tasks and post-test had a correlation of .44 while proportional/porportional correlated at .32. Also, combinatorial/probabilistic correlated at .42 compared to .34 for combinatorial/combinatorial. Overall correlations, i.e., correlations representing combined reasoning types, were consistently higher. Again, this indicates a lack of direct correspondence between specific formal reasoning skills and similar areas in genetics problems since overall correlations are higher than the individually considered factors.

The factor analysis of interview tasks and post-test items also failed to support the hypotheses that formal reasoning skills could be related directly to genetics problems. All three interview tasks loaded together, making it is more

likely that intellectual levels were being factored out rather than specific reasoning skills.

ANOVAs indicated significant main effects for both the intellectual levels and reasoning types from the interview tasks and post-test scores. In each consideration post hoc analysis of the ANOVA results indicated significantly higher unit test or post-test mean scores for the students with higher scores on the Piagetian measures of intellectual ability.

Implications

The most obvious implication seen in the results of this study is the need to identify appropriate content for instruction based on intellectual development of students. Genetics is an extremely valuable domain of study within biology, but great care should be taken to assure that when genetics problems are included in the curriculum the students are capable of doing what they are asked to do. Presentation of formal concepts seen in Mendelian problems to students who are concrete-operational will most certainly result in frustration. This would imply that Mendelian genetics has little place in the middle-school or high school classroom where a high percentage of students are non-formal. The impossibility of presenting the formal concepts of genetics as concrete instruction should show the inappropriateness of this study for many science classrooms (Schneider & Renner, 1980).

We can say with a high degree of certainty that formal thought is necessary for solving Mendelian genetics problems, but we do not know enough about formal-operational thought to relate its characteristics directly to what we perceive to be the specific reasoning type necessary in solving genetics problems. This conclusion should serve as a warning that a student's success on a specific Piagetian task used to assess his intellectual level does not assure his success in curriculum content that is assumed to require the same specific reasoning type.

Literature Cited

DeLuka, F.P. (1979). Application and analysis of an electronic equivalent of Piaget's first chemical experiment. Journal of Research in Science Teaching, 16(1), 1-11.

Haley, S.B., & Good, R.G. (1976). Concrete and formal thought: Implications for introductory college biology. The American Biology Teacher, 38(7), 407-412.

Inhelder, B., & Piaget, J. (1958). The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books.

Maloney, D.P. (1981). Comparative reasoning abilities of college students. American Journal of Physics, 49(8), 784-786.

McKinnon, J.W., & Renner, J.W. (1971). Are colleges concerned with intellectual development? American Journal of Physics, 39(9), 1047-1052.

Schneider, L.S., & Renner, J.W. (1980). Concrete and formal teaching. Journal of Research in Science Teaching, 17(6), 503-517.

Shayer, M., & Adey, P. (1981). Towards a Science of Science Teaching. London: Heinemann Educational Books.

Walker, R.A., Mertens, T.R., & Hendrix, J.R. (1979). Formal operational reasoning patterns and scholastic achievement in genetics. Journal of College Science Teaching, 8(3), 156-158.